Nano-Enabled Low Index UV Anti-Reflection Coatings for Plastic Optics

Mirror Technology Workshop

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NASA SBIR Phase II

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Outline

- NASA's Needs for UV AR coatings
- Limitations in Existing AR Coating for Polymer Optics
- Program Objective
- Project Achievements
- Summary

NASA's Needs for UV Anti-Reflection Coatings

- The coatings should be applied on
  - Plastic substrates (PMMA)
  - Large size
  - Complex shape
- The upcoming EUSO mission calls for the use of large plastic Fresnel lenses (2.5 m) for orbiting cosmic ray telescopes which gather light in the 300-400 nm UV band from Cerenkov radiation in the atmosphere.

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Limitations in Existing AR Coating for Polymer Optics

- Evaporated coatings - Ion Assisted deposition, dielectric materials
  - Limitations:
    - Requires vacuum chamber, limited area
    - Plastic substrates cannot be heated to optimum temperature
    - CTE mismatches between substrate and coatings - limited temperature range for finished optics
    - Film stress bends substrate if large
- Dupont Teflon low index fluoropolymer
  - Limitation: fixed index (~1.35, not ideal for PMMA)
- There is a need for low index materials (ideally graded or tailored index)

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Program Objective

- To develop an UV anti-reflection (AR) coating technology for PMMA substrates, which meets the following requirements:
  - Over 99% transmission in the UV wavelength range
  - Long environmental stability
  - Survivability from standard optical surface cleaning
  - Large area and conformal applicability

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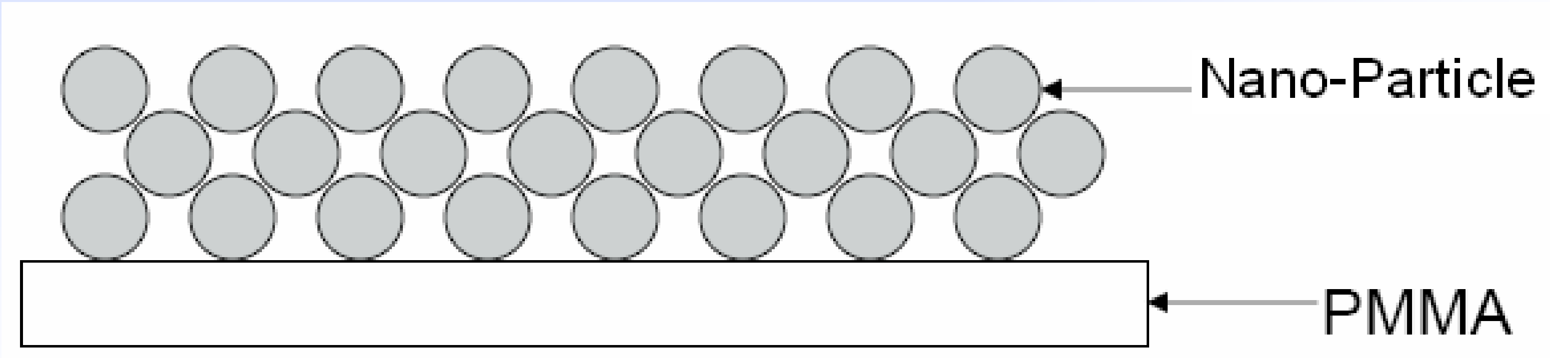
Advantages of Agiltron/MIT Approach

- Nano enabled porous structures
- Low index (1.2~1.3)
- Graded index or tailored index
- Precision thickness control
- Low cost wet coating process
- Very large area coating capability
- Complex shape conform coating capability

Schematic Diagram of Coating Structure

- The coating is a porous structure caused by lose nano-particle packing
- The coating can be fabricated using large scale wet chemistry processing



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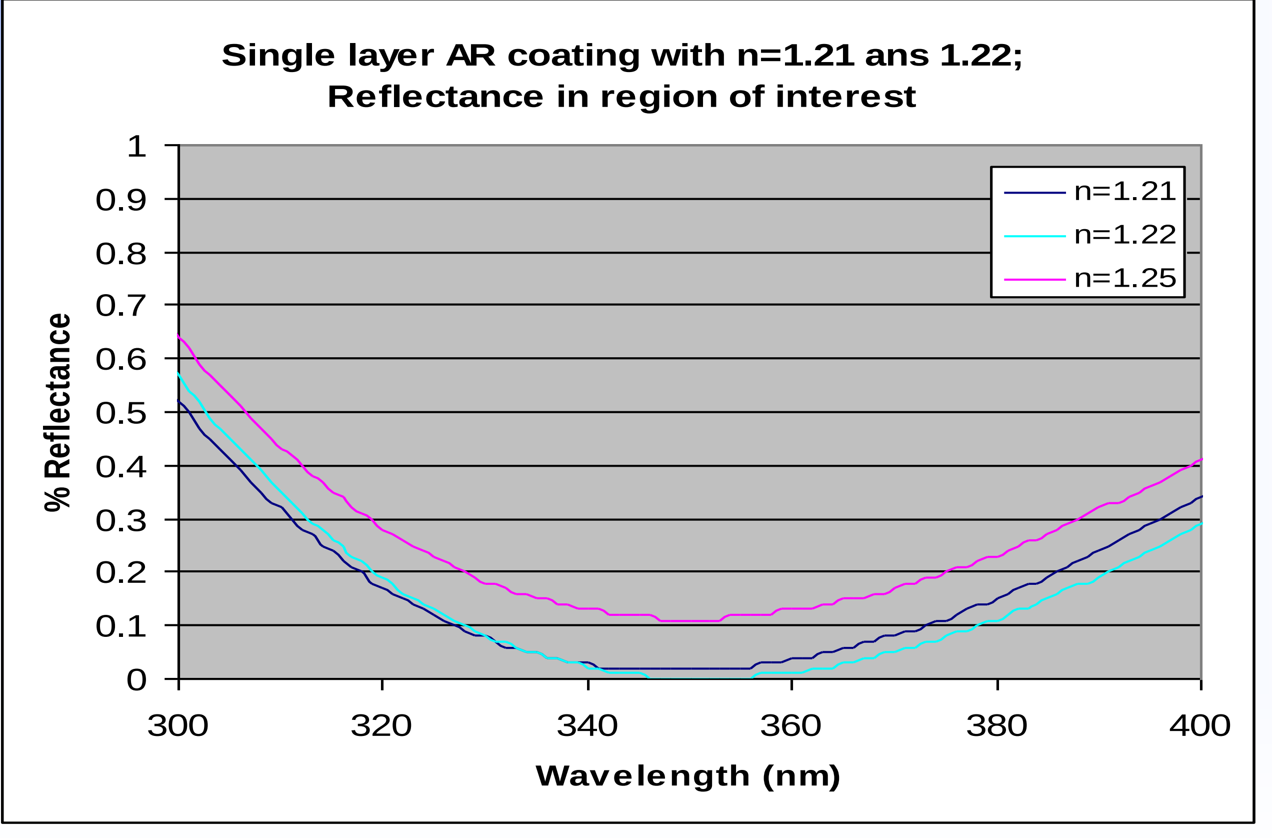
Simulated Reflectance from Single Layer AR Coating on PMMA

- An index of ~1.21-1.22 would provide best AR qualities



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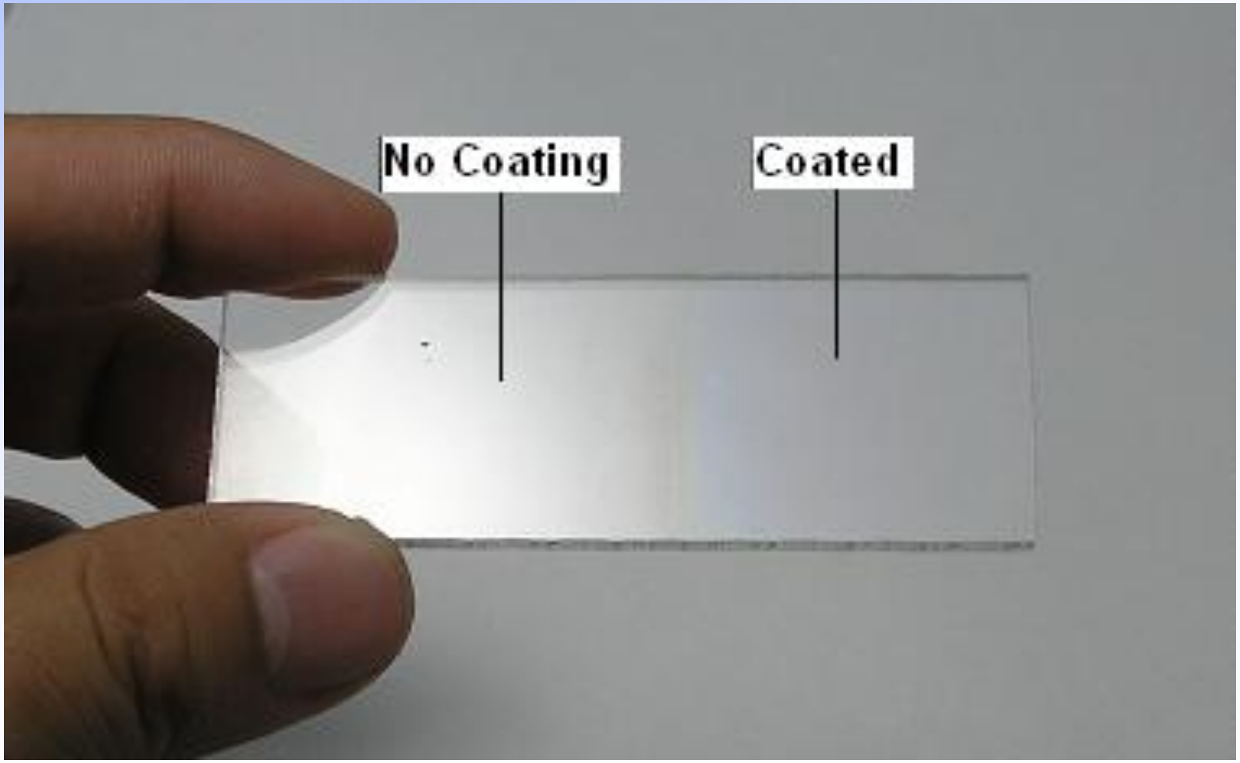
Reflection Comparison of AR Coated and Non-Coated PMMA Substrate

- Index of coating: 1.20; Thickness of coating: 71 nm



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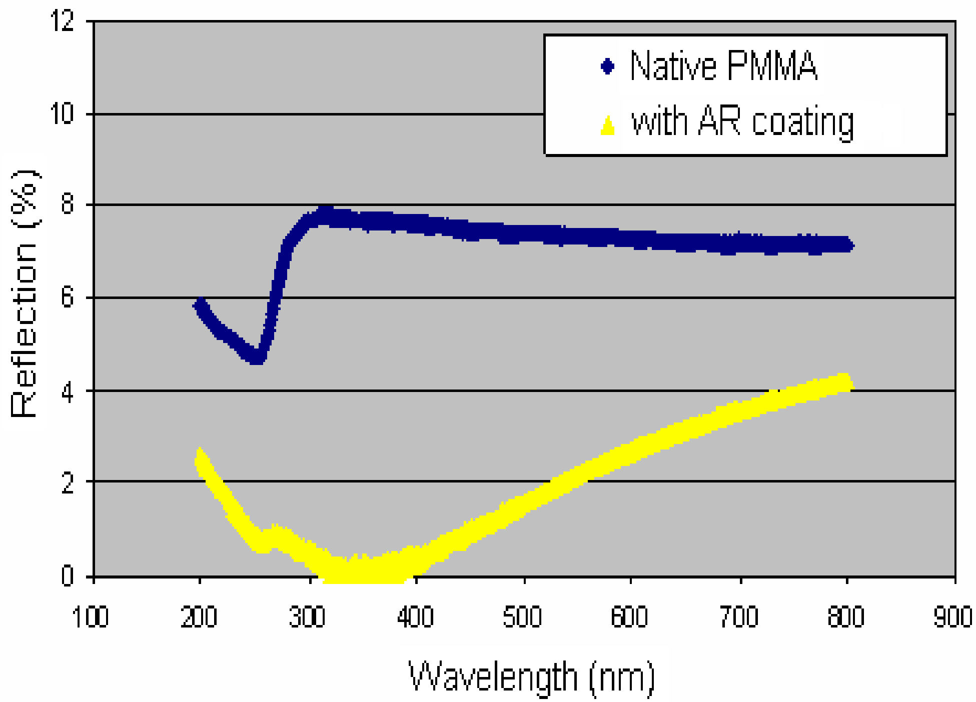
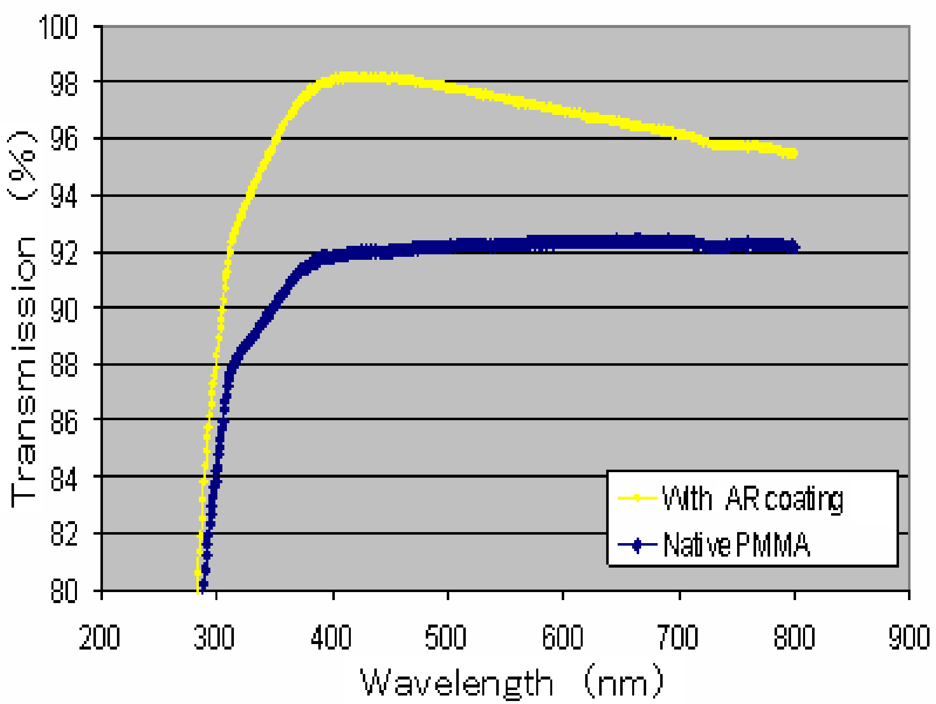
Performance of Single Layer AR Coating on PMMA with an Index of 1.20

- Reduced UV reflectance of < 0.5% for AR coated PMMA (300~400nm), compared to >7% for native PMMA
- Improved UV transmittance of PMMA substrates, with transmittance ≈ 98% (at 400nm) for AR coated PMMA, compared to 92% for native PMMA

Reflection

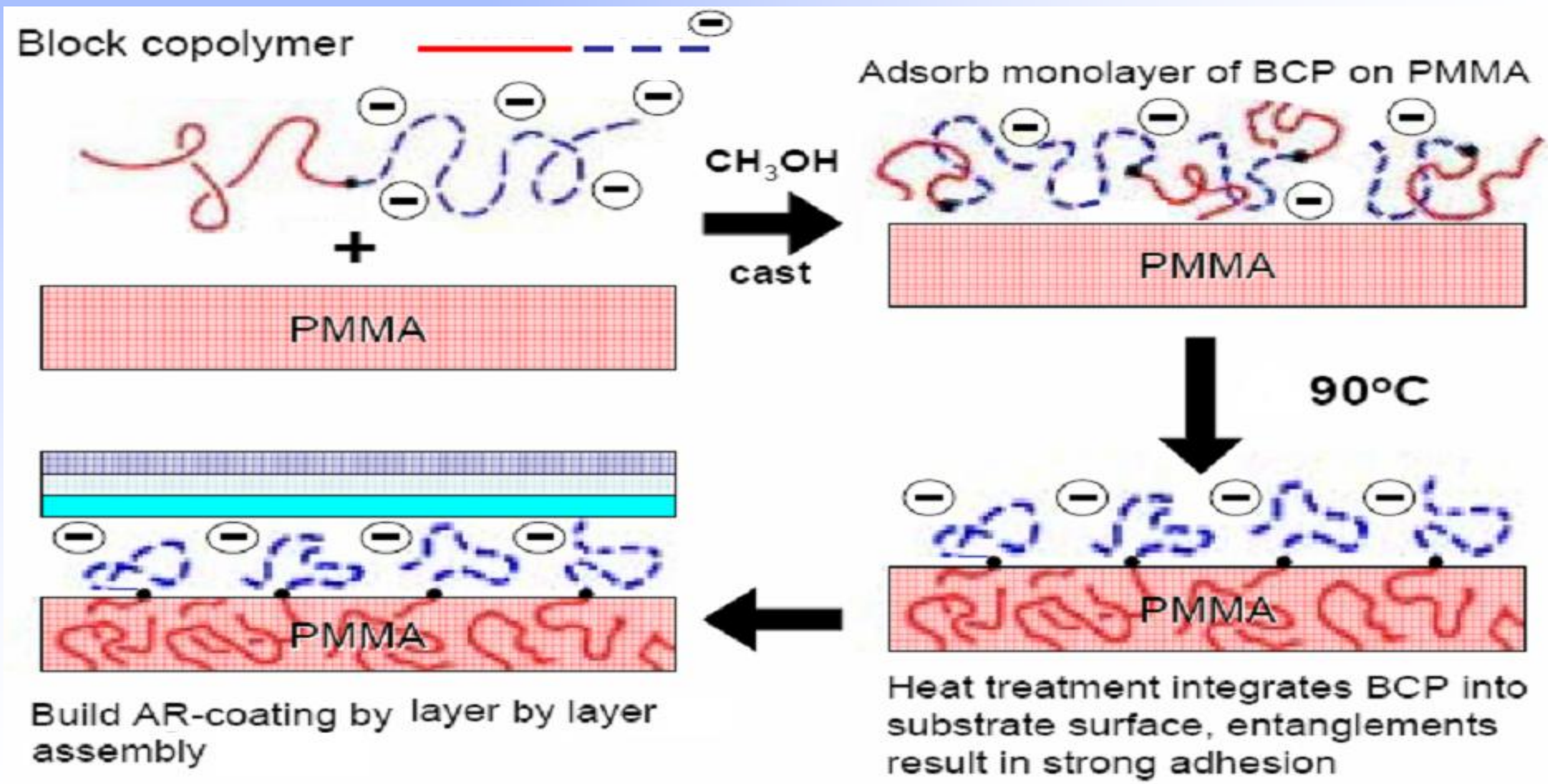


Transmission



PMMA Surface Modification to Enhance Coating/PMMA Integrity

- Block copolymer (BCP)
  - Red section is PMMA affinitive, Blue section is negative charged
- AR coating on the BCP layer survived the cleaning procedure suggested by NASA

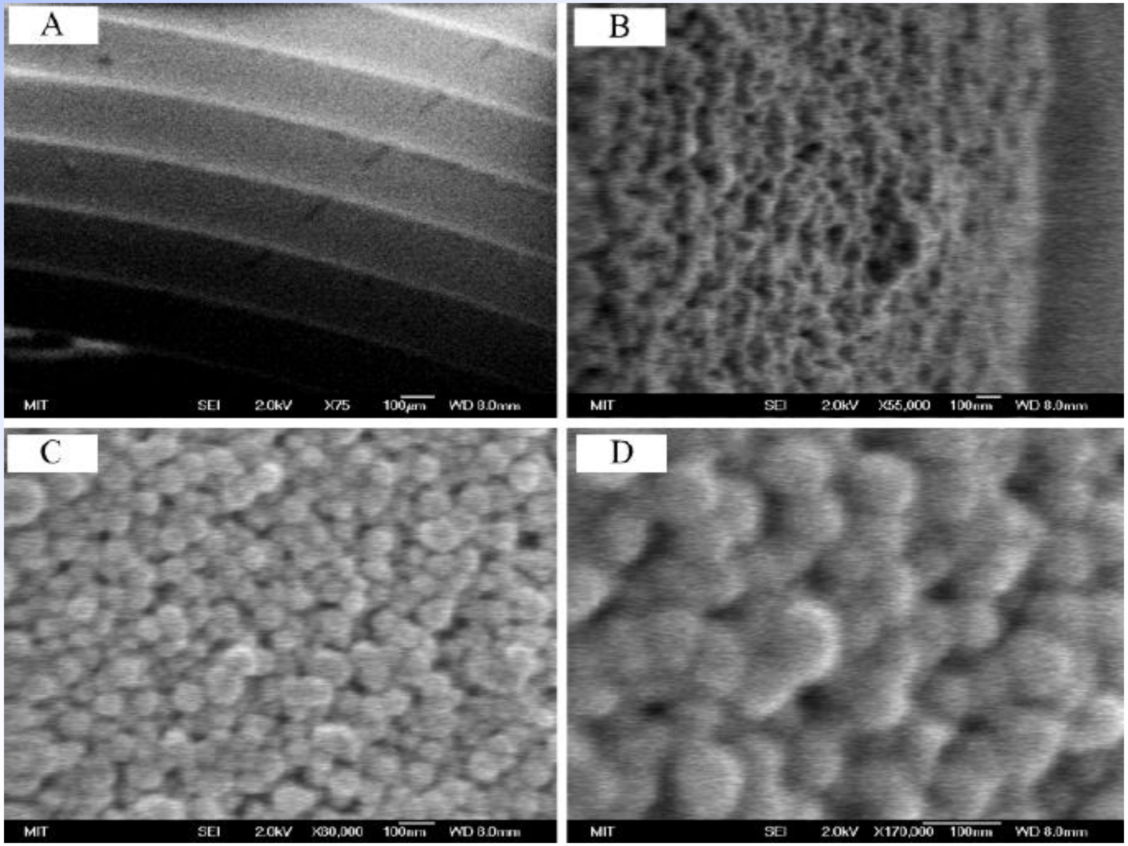


AR Coating on PMMA Fresnel Lens

- Conformal coatings can be applied on surfaces of Fresnel lenses.
- High porosity in the coating leads to low refraction index of the coating.

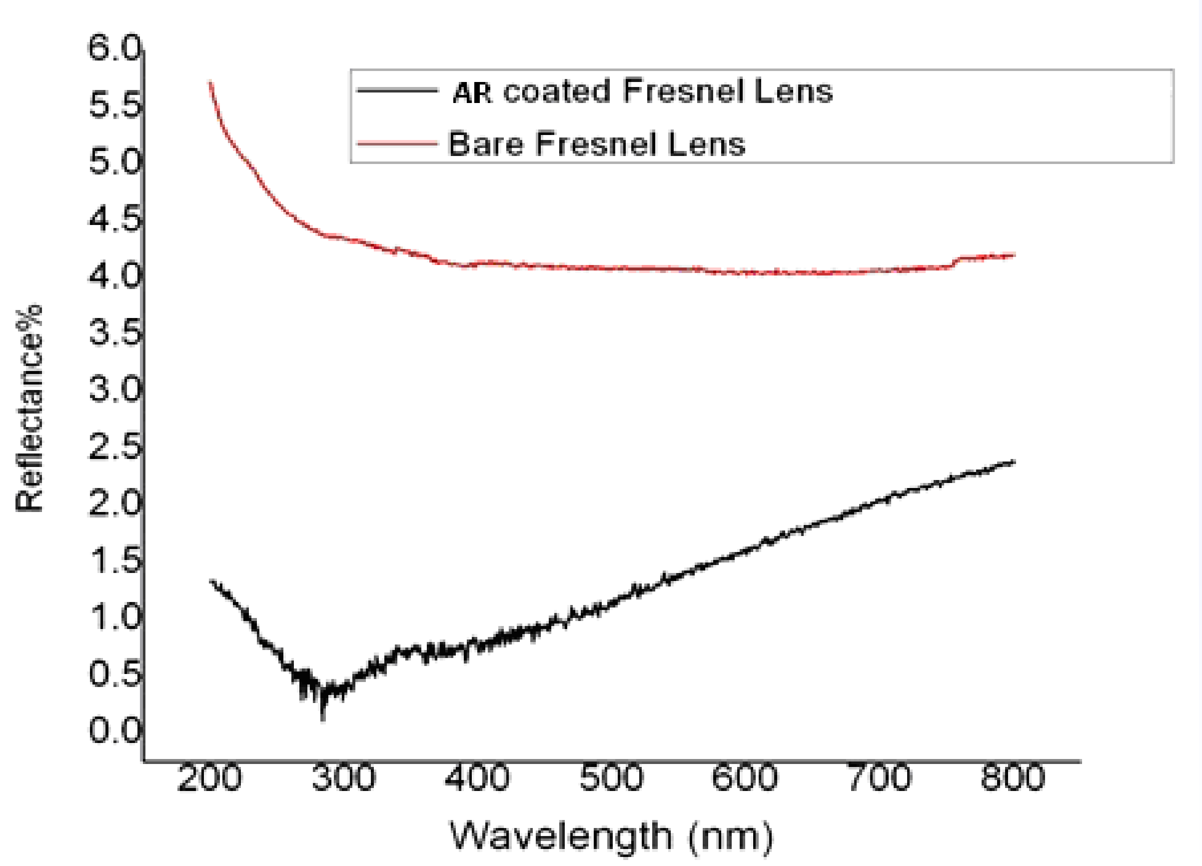
PMMA Fresnel Lens

SEM of the AR coating



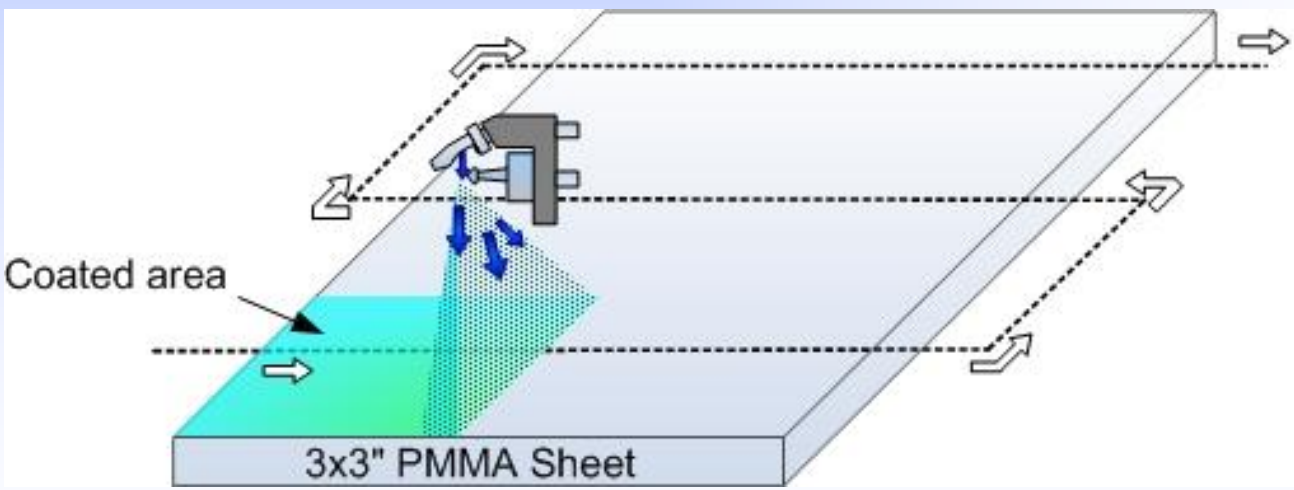
Performance of AR Coating on Fresnel Lens

- On the flat area, the AR coating reduces reflection down to < 0.6% reflection in UV range
- The performance of the coating on Fresnel Lenses is being tested



Large Scale Coating Development

- Current coatings are deposited by multiple dip-coating, which is not easy to scale up for very large substrates, and needs a large amount of coating solutions.
- We are developing a spray coating for large-scale substrates.



Summary

- The Agiltron/MIT team has successfully demonstrated the feasibility of the nano-enabled UV anti-reflection coating technology
- We have achieved enhanced UV transmittance up to 98% at ~ 400nm, which represents a 6~7% increase compared to bare PMMA substrates
- Interfacial layer has been developed to enhance the coating/PMMA integrity, the proposed UV AR coating is being built on the surface modified PMMA
- This AR coating has been applied on PMMA Fresnel lenses with conformal morphologies
- A large scale coating process are being developed for large plastic optics required by NASA

Acknowledgement

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